SEPARATION OF MIXED PLASTIC WASTE USING ELECTROSTATICS

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SEPARATION OF MIXED PLASTIC WASTE USING ELECTROSTATICS

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DISCLAIMER

This report was prepared for the Ontario Ministry of Environment and Energy (formerly Ministry of the Environment) as part of a Ministry funded project. The views and ideas expressed in this report are those of the author and do not necessarily reflect the views and policies of the Ministry of Environment and Energy, nor does mention of trade names or commercial products constitute endorsement or recommendation for use. Note, all references to Ministry of the Environment in this report should read Ministry of Environment and Energy.

CONTENTS

Introduction

Currently there is no economically satisfactory method of separating mixed plastics such as found in "blue box" collections. Thus the development of an effective dry process for separating even some of these plastics should provide major advantages leading to the more effective use of primary resources, reduction in the amount of land fill and reduction in the quantity of non-biodegradable litter.

The need for the process exists today as witnessed by requests made from industrial recyclers. Methods of recycling the separated plastic materials currently exist and the economic viability of these processes depends very heavily on the purity of the feedstock. If a research project leads to acceptable levels of separation and demonstrates the economics of the process in pilot plant scale operation, indications are that it would be immediately accepted by the recycling industry. The mixed plastics required for the process could be obtained in virtually unlimited quantities in a very short period of time by allowing plastics to be used in the "blue box" recycling schemes.

The multi disciplinary research team which has worked on the project comprises faculty members currently involved in research in two Research Centres of the University of Western Ontario: Applied Electrostatics and Surface Science. Over the past eighteen years, individually, and jointly, the researchers have successfully dealt with difficult separation problems involving ores, flyash, coal, etc.

A total of 21 papers and 1 book dealing with electrostatic mineral separation have been generated form the Applied Electrostatics Research Centre and several dry separation apparatus have been developed:

a) The electrostatic separation tower.

b) The electrostatic conveyor with troughs collecting the separated fraction from the surface of a fluidized bed;

c) The electrostatic loop for separation of very fine particles;

d) The vibrated fluidized bed operating at minimum fluidization velocities with H.V. electrodes and vacuum extraction from the surface of the bed;

e) The Alternating Potential Electrostatic Separator of Particles with different Physical Properties. This unit gave excellent results in beneficiation of gold ores and in removal of unburnt carbon from flyash collected from electrostatic precipitators. A 24 ton/day pilot plant was built on this principle in U.K. The development has received world wide patent coverage with rights obtained by Canadian Patents and Development Limited.

While most of the work at the University of Western Ontario has been concentrated on impure materials such as ores, some fundamental research work was carried out on triboelectrification of plastics with various metals. The triboelectrification experiments were carried out both in air and in vacuum under controlled conditions. The doctoral thesis of W.D. Greason (U.W.O. 1971) has established the work functions of 12 commonly encountered plastics in industry. Triboelectrification is a key process in electrostatic separation of materials.

Considering the extensive experience of the Research Team on: triboelectrification, various separation apparatus, the fundamental work on the work functions of plastics, as well as, the excellent facilities of the Applied Electrostatic Research and and Surface Science Centres, the extension of the work into the separation of plastics was a natural consequence.

A proposal was submitted to the Ontario Ministry of the Environment, Waste Management Branch on November 27, 1990 for a research project entitled "Separation of Mixed Plastic Waste using Electrostatics". Approval was received for a preliminary investigation (Phase I) supported by both MOE and EPIC as shown below.

MOE $20,250.00

EPIC $ 6,750.00

EPIC - Environment and Plastics Institute of Canada

Dr. Fred Edgecombe, Executive Director, Phone: (416) 449-3444

The results of this preliminary investigation are shown in the Appendix B of this report.

Building upon these results, a request was submitted to M.O.E. to continue the work focused on more specific applications and developing laboratory electrostatic separation apparatus eventually suitable for a pilot plant scale-up.

The Ministry of the Environment, Waste Management Branch agreed to support the continuation of the project (Phase II).

The continuation was fully supported by MOE with a budget of $57,000.

EPIC

Suite 104
Don Mills, Ontario
M3B 2W7

Fax: (416) 449-5685

January 29, 1993

The Honourable Ruth Grier
Minister of the Environment
Province of Ontario
135 St. Clair Avenue, W.
Toronto, Ontario
M4V 1P5

Dear Mrs. Grier:

Re: Separation of Mixed Plastic Waste Using Electrostatics

May I recommend to you the report dated January 21, 1993 from the University of Western Ontario's Applied Electrostatics Research Centre on the Separation of Mixed Plastic Waste Using Electrostatics, Phase II supported by the Ontario Ministry of the Environment, Waste Management Branch and the Environment and Plastics Institute of Canada (EPIC).

The work described in the report is an excellent example of cooperation between your Ministry, Academia and Industry.

As a co-sponsor of the research, EPIC has been involved in all phases of the activity and is of the opinion that the results will be useful in facilitating the purification of some specific recycled plastic materials. This in turn will enable the application of these substances in sophisticated manufacturing operations.

I have noted substantial interest in the work being expressed by companies in the plastic industry and I am hopeful that in the near future we shall see the research moved from the laboratory to the next step up in scale, ultimately leading to commercial operations.

It has been a pleasure working with your staff and that of the University and we look forward to future endeavours.

Yours very truly,

Fred Edgecombe

F.H. Edgecombe, Ph.D.
Executive Director

Final Report on Project:

Separation of Mixed Plastic Waste Using Electrostatics Phase II

Supported by the Ontario Ministry of the Environment, Waste Management Branch
(File No. INR 04174)
and
The Environment and Plastic Institute of Canada (EPIC)

Scientific Liaison:
Mrs. Irene Pater, MOE, Waste Management Branch
and
Dr. Fred Edgecombe, Environment and Plastics Institute of Canada

Project Engineer:
L. Boccanfuso

University of Western Ontario Investigators:
Professor I.I. Inculet (P.I.), Electrical Engineering
Dr. G.S.P. Castle, Electrical Engineering
Dr. J.D. Brown, Materials Engineering

21 January 1993

Phase II, Executive Summary

Phase II of the Separation of Mixed Plastic Waste Project has been very successful. Key developments were made in the areas of equipment design and manipulation of process parameters. In particular a new system for charging the plastic feed stream was developed. An application for United States patent protection (Application Number 07/952,096 dated September 28, 1992) of this technology has been filed. (The University of Western Ontario owns the rights to this new technology and upon the Patent Law Office advice and pending new developments, applications in other countries including Canada may be filed as late as September 28, 1993.)

These accomplishments resulted in excellent separations (in terms of both product purities and recoveries) of important plastic mixtures. These include the High Density Polyethylene (HDPE)/Polypropylene (PP) system, the Polyethyleneterephthalate (PET)/Polyvinylchloride (PVC) system (including the case where a small amount of PVC contamination is present), and systems involving Polystyrene (PS). Sample values are listed below.

Feed Stream	Initial Composition (%)	Extract Content (Or Purity) (%)	Recovery (%)
PVC PET	50.0 50.0	99.2 99.9	80.3 89.1
PVC PET	1.0 99.0	3.6 100.0	64.0 79.4
HDPE PP	50.0 50.0	99.6 99.7	84.3 89.3
HDPE PP	90.0 10.0	99.9 43.9	84.6 95.0
HDPE PP PS	42.5 42.5 15.0	92.0 96.1 99.6	72.2 90.7 73.8
PP PS	50.0 50.0	94.1 98.8	96.2 91.9
PP PS	5.0 95.0	30.9 99.9	95.0 85.1

Scale-up of the process from the laboratory to a pilot-plant stage was also investigated. An initial design for a production facility capable of processing 1000 lbs/hr of material was completed and quotations have been submitted at the request of two Canadian corporations.

EQUIPMENT AND PROCESS SPECIFICATIONS

Figure 1 is a schematic of the electrostatic separation system. It contains three sections: charging, separation and collection. The plastic mixture to be processed is fed into the charging stage. Using new technology developed during the course of the project the particles obtain an electrostatic charge. One component charges positively, the other negatively thus providing a basis for their eventual separation. Following this the particles are fed to an electrostatic separation tower. This consists of two (positive and negative) high voltage aluminum electrodes (45 cm x 180 cm) encased in a 0.75 m x 0.9 m x 3.6 m high enclosure.. As the particles fall through the tower they are deflected towards one electrode or the other, depending upon their charge. The collection system is located at the base of the tower. This contains three collection areas. One area collects the negatively charged material, while the another collects the positively charged material. Material that has insufficient charge for separation is collected in the central area. This material is referred to as "middlings" and can be reprocessed.

Experiments were performed in a "batch mode" of operation. The majority of tests involved single stage (i.e. "once through") processing. In a few cases one of the product streams was reprocessed to improve the quality. Batch sizes were in the order of 40 to 100 grams. The high voltage electrodes were maintained at +/- 50 kvolts. Atmospheric conditions (relative humidity and temperature) were recorded at the beginning and end of each test. Coloured material was used to allow for visual analysis of the product streams. Except where noted the plastic was all post-industrial material, obtained from the Environment and Plastics Institute of Canada (EPIC). Average size of the material was 2 - 5 mm.

The results are presented in terms of extract content (or purity) and recovery. These terms are defined as follows:

For Material A:

$$\textit{Extract Content} = \frac{\textit{Mass of Material A in Product Stream}}{\textit{Total Mass of Product Stream}}$$

$$\textit{Recovery} = \frac{\textit{Mass of Material A in Product Stream}}{\textit{Mass of Material A in Feed Stream}}$$

As an example consider a mixture of 10 grams of PET and 10 grams of PVC. After processing three product streams are obtained. Stream 1 contains 0.8 grams of PVC and 7.2 grams of PET. Stream 2 contains 8.0 grams of PVC and 1.6 grams of PET. The third stream contains the remaining 2,4 grams of material (i.e., the middlings). The extract contents and recoveries are:

From stream #1

$$\textit{Extract Content of PET} = \frac{7.2}{7.2+0.8} = 90\%$$

$$\textit{Recovery of PET} = \frac{7.2}{10.0} = 72\%$$

and from stream #2

$$\textit{Extract Content of PVC} = \frac{8.0}{8.0+1.6} = 83.3\%$$

$$\textit{Recovery of PVC} = \frac{8.0}{10.0} = 80\%$$

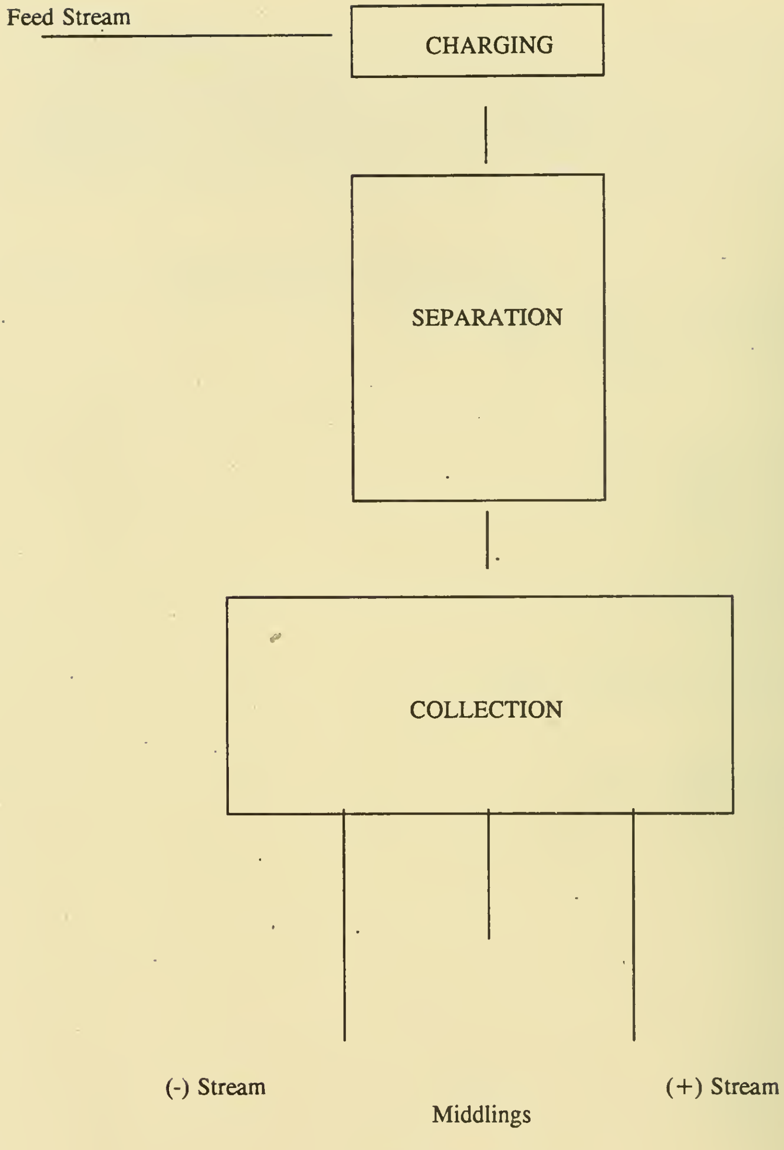


Figure 1 - Electrostatic Separation System for Plastics

PET/PVC SEPARATION

Figure 2 illustrates the excellent results obtained with a 50/50 (weight per cent) PET/PVC mixture. Extract contents in excess of 99% and recoveries in the neighbourhood of 85% were observed. The results are significant since the removal of PVC from PET is an important industrial concern. Small quantities of PVC (as little as 150 parts per million (ppm)) contamination can seriously affect the processing of PET.

To examine whether the process could achieve PET extract contents in excess of 99.985% (i.e., less than 150 ppm PVC content) tests were carried out using PET/PVC mixtures with 1% PVC contamination. Post-consumer material was acquired from a major recycling firm for these experiments. Table 1 summarizes the data obtained.

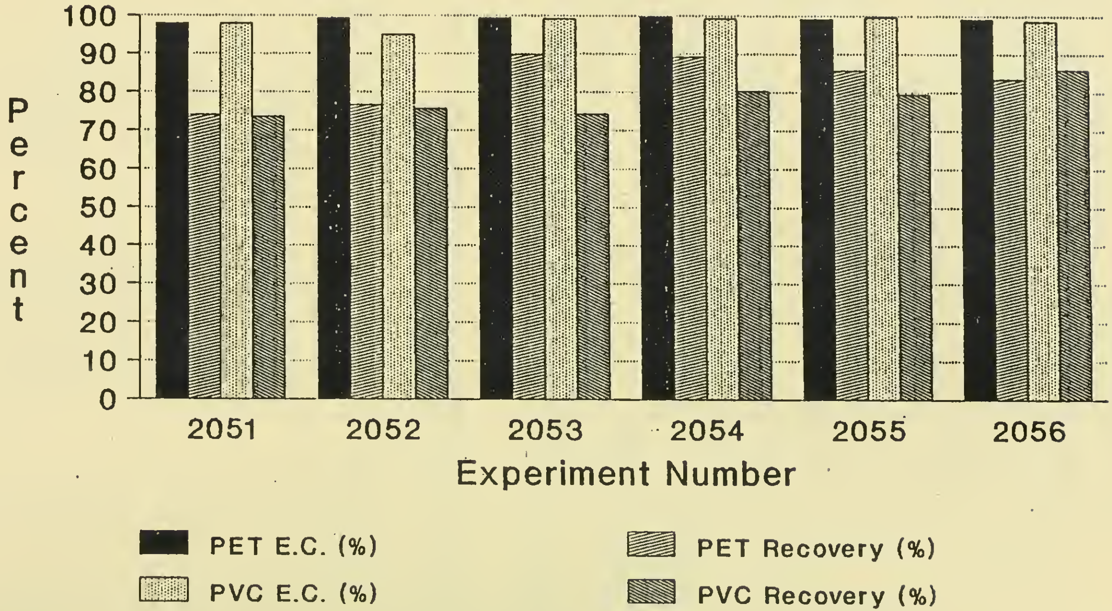
It can be seen that some degree of pre-conditioning was required in order to achieve product of acceptable purity. When acceptable purity was attained product recoveries were in the 80% range. These results are particularly noteworthy in that the removal of a small amount of PVC contamination from a post-consumer PET waste stream represents an actual problem encountered in the recycling industry.

TABLE 1 - RESULTS FROM PET/PVC* PROCESSING

Pre Conditioning	Relative Humidity (%)	PET Purity (%)	PET Recovery (%)
NO	47.5	99.62	90.0
NO	46.7	99.23	94.1
NO	46.3	99.21	94.2
YES	40.4	100.0	76.8
YES	41.6	99.98	78.1
YES	46.6	100.0	89.6
YES	40.7	100.0	77.6
YES	39.1	100.0	79.4
YES	43.0	99.97	74.1

* Initial Composition 1% PVC, 99% PET Post-Consumer Material

PET/PVC Separation



Initial Composition 50/50

Figure 2

HDPE/PP SEPARATION

During Phase I of the project little success was noted in the separation of a mixture of HDPE and PP. The results that were typically obtained can be seen in figure 3. Although some good separations were noted, the quality was far below that seen with the PET/PVC mixtures. The degree of separation also appeared to be quite variable.

In order to address this problem a modification was made to the charging system. With this change a dramatic improvement took place. The results obtained are shown in figure 4. Extract contents in excess of 99% and product recoveries of 90% were now being achieved. This presented another possible contribution to the recycling industry as HDPE and PP account for a majority of the plastic material now collected in curbside programs.

To investigate the versatility of the system, tests were also conducted using different initial compositions. Figures 5 and 6 summarize these findings. It is evident that the system can efficiently handle a wide variety of feed stream compositions.

TWO AND THREE COMPONENT SEPARATIONS INVOLVING POLYSTYRENE

The processing of a mixture of HDPE/PP/PS presented a new type of test for the system. No experiments had previously been preformed using a 3 component feed stream. It was believed that with a 3 component stream separation would still occur. The third component would simply remain neutral during the charging process and thus fall in the central bin during the separation stage. The other two components having obtained positive and negative charges would be collected as usual. However, it was impossible to predict with what degree of efficiency this would occur.

An initial composition of HDPE 42.5%, PP 42.5% and PS 15% was chosen[1]. Preliminary tests indicated that the material required two stages of processing. In the first stage the HDPE and PP streams could be collected. The PS stream still contained a significant amount of PP so reprocessing of this stream was necessary.

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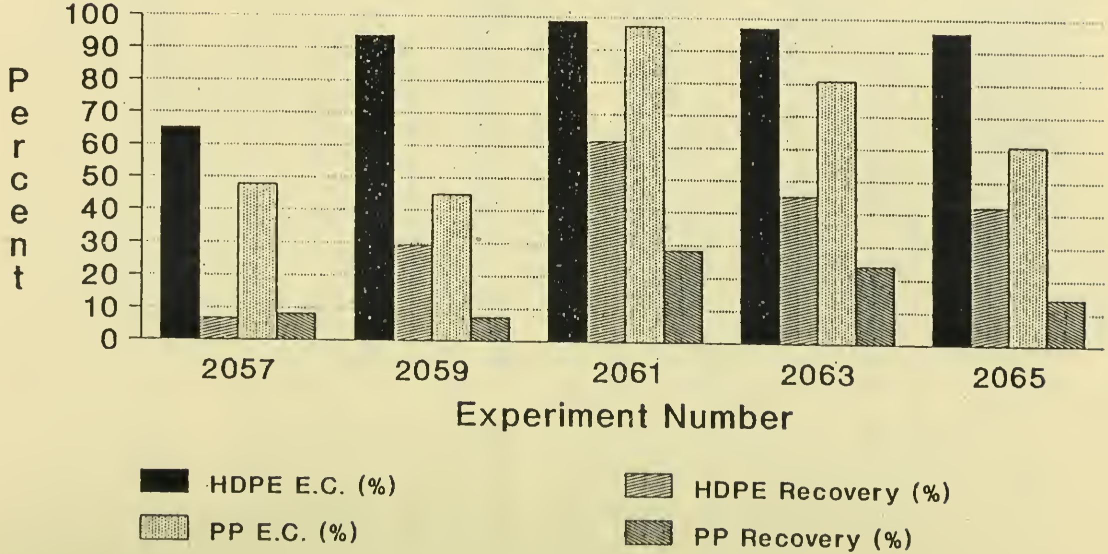
[1]Personal communication, Dr. Fred Edgecombe, EPIC.

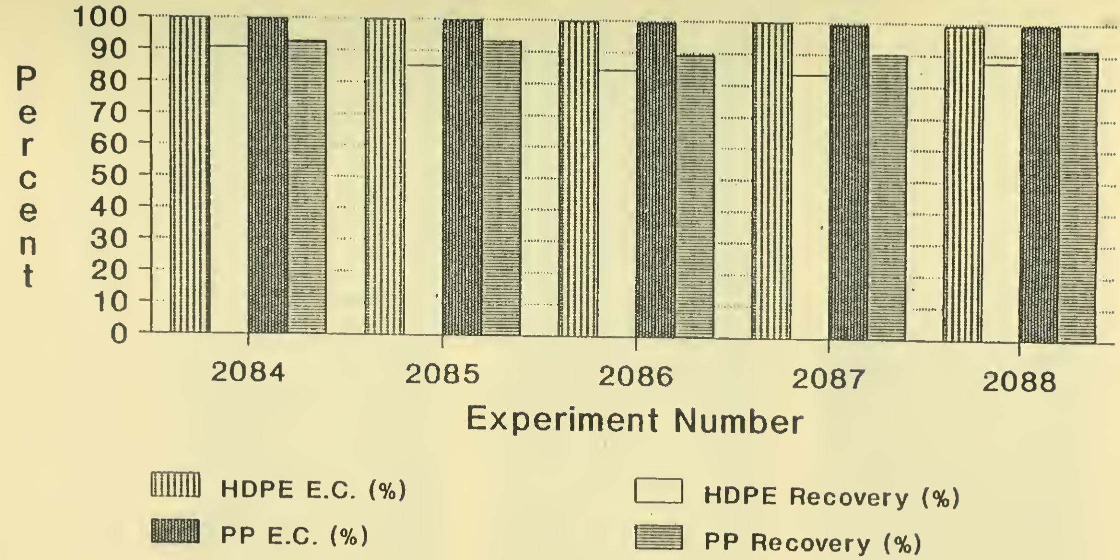
HDPE/PP Separation
Typical Phase I Results



Initial Composition 50/50

Figure 3

HDPE/PP Separation
Phase II Results - New Charging System



Initial Composition 50/50

Figure 4

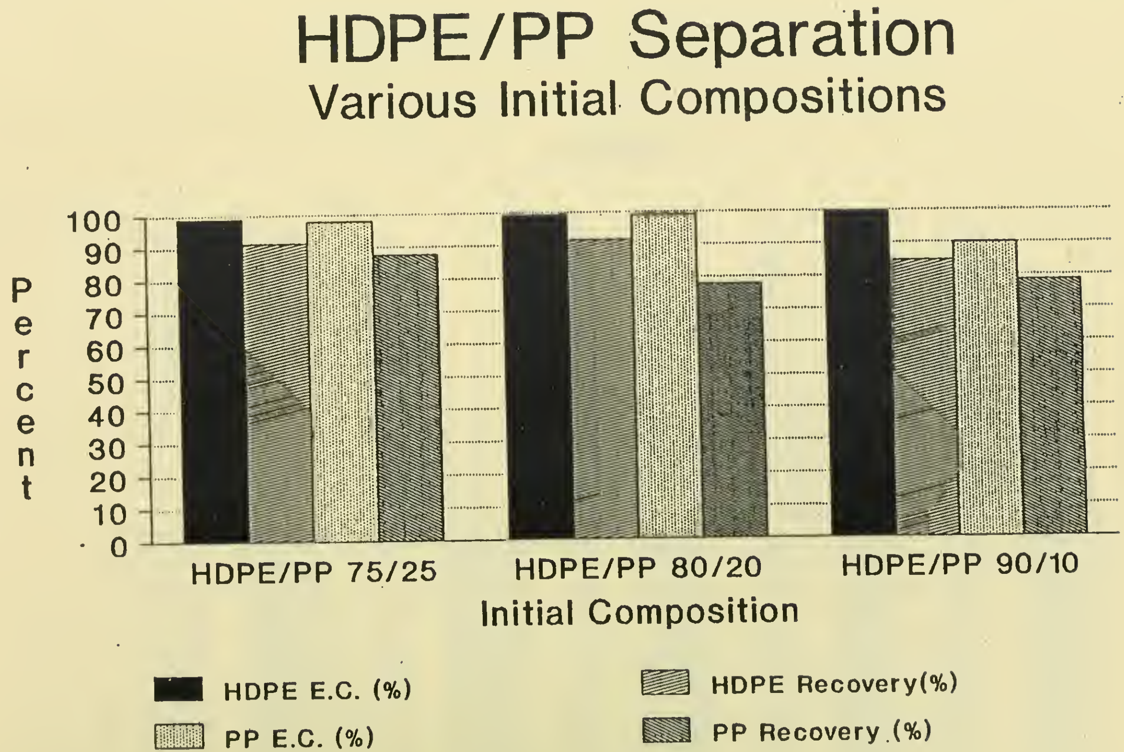

HDPE/PP Separation
Various Initial Compositions
Percent
100
90
80
70
60
50
40
30
20
10
0
HDPE/PP 75/25
HDPE/PP 80/20
HDPE/PP 90/10
Initial Composition
HDPE E.C. (%)
PP E.C. (%)
HDPE Recovery(%)
PP Recovery (%)

Figure 5

HDPE/PP Separation
Various Initial Compositions

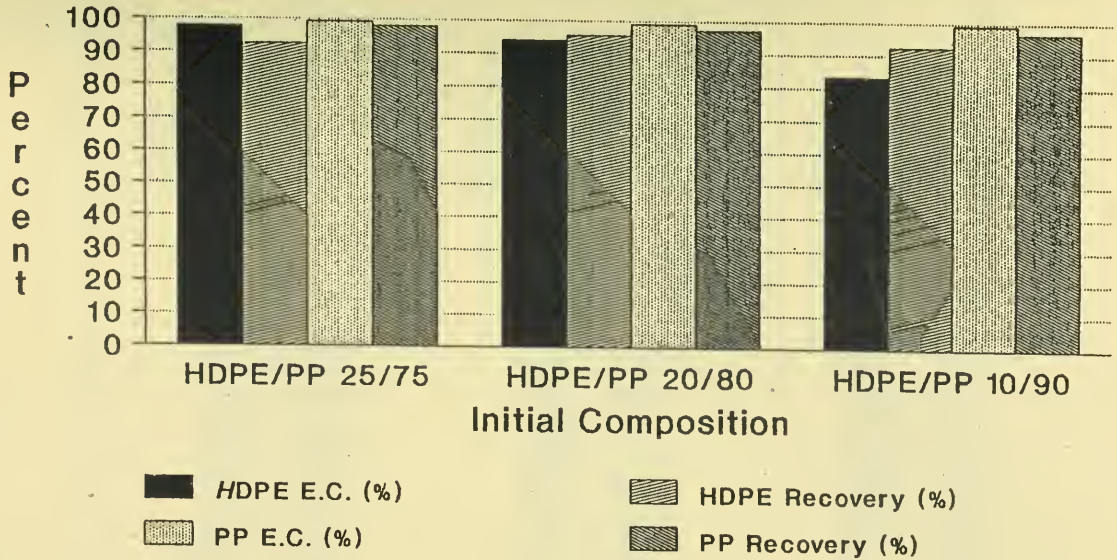
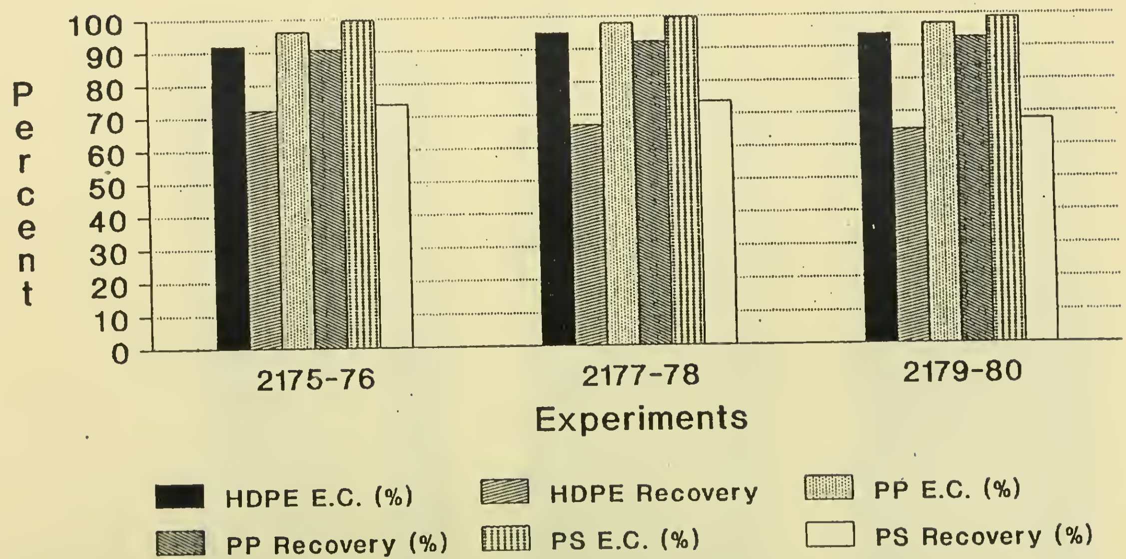


Figure 6

HDPE/PP/PS Separations
Two Stage Processing



Initial Composition 42.5/42.5/15

Figure 7

Figure 7 illustrates the results obtained. Extract contents well in excess of 90% were noted for each component. The recovery of PP was excellent while recoveries for HDPE and PS were significantly poorer. This was attributable to the tendency of the HDPE and PS particles to adhere to the inside of the charging system and not feed into the separation tower. This was likely due to the relatively large amount of charge acquired by these two materials. A reduction in the amount of charge acquired by the particles, while ensuring that a significant amount remains for separation, could solve this problem.

The separation of different mixtures of PS and PP was also explored. The results can be seen in Figure 8. Good extract contents and recoveries were achieved with a 50/50 initial composition. Removal of small amounts of PP (5 per cent or less) in order to obtain essentially pure (in excess of 99 %) PS was also possible.

NATURAL HDPE/ COLOURED HDPE SEPARATIONS

The possibility of using this new separation system to classify material according to colour was investigated. Three different 50/50 mixtures of HDPE (coloured) and natural HDPE (NaHDPE) were processed. Test results are shown in Figure 9. Although some improvement in product purities can be noted, the recoveries are poor.

EQUIPMENT DESIGN

As noted previously the second goal of Phase II was to further study the apparatus and process conditions so that industrial scale production equipment could be designed. For this reason a series of tests was conducted to examine the effect of important process parameters. These parameters deal almost exclusively with the new charging system (for which patent protection[2] is presently being sought) and cannot be discussed here. At this time it is sufficient to note that a design was completed for a pilot-plant capable of processing 1000 lbs/hr of material. Discussions are ongoing with a number of firms concerning possible construction of such a facility.

[2] The Ministry of the Environment has the full details which will be made public when the patents are issued.

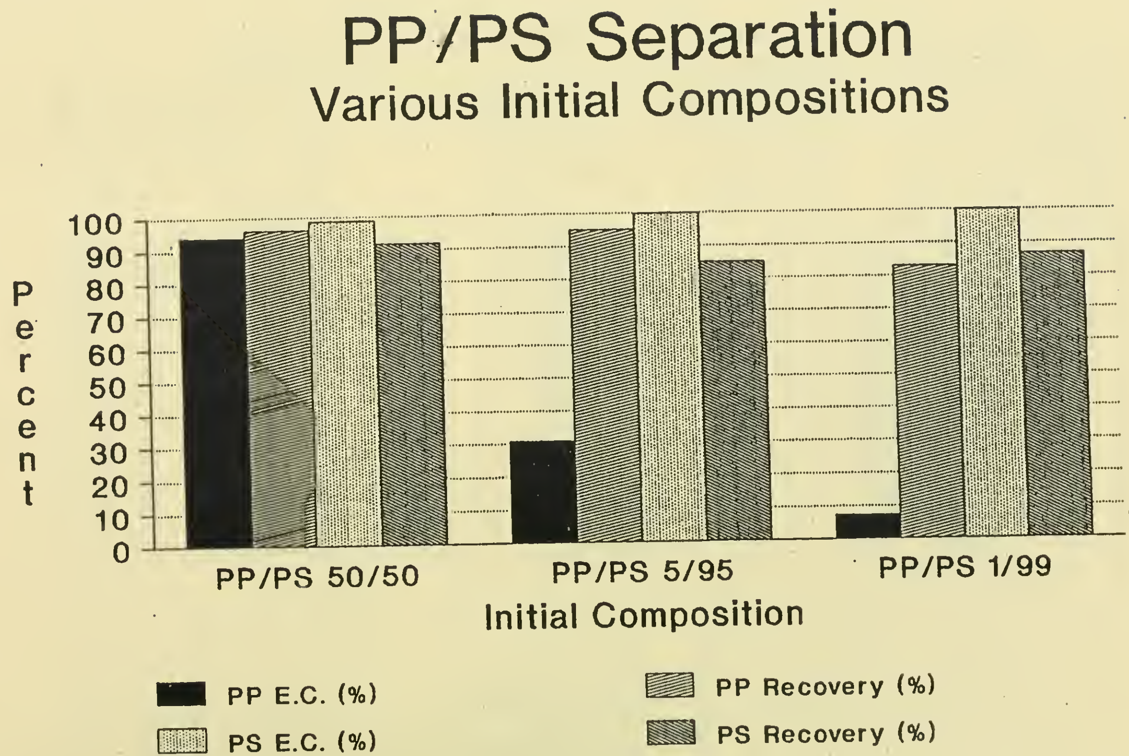
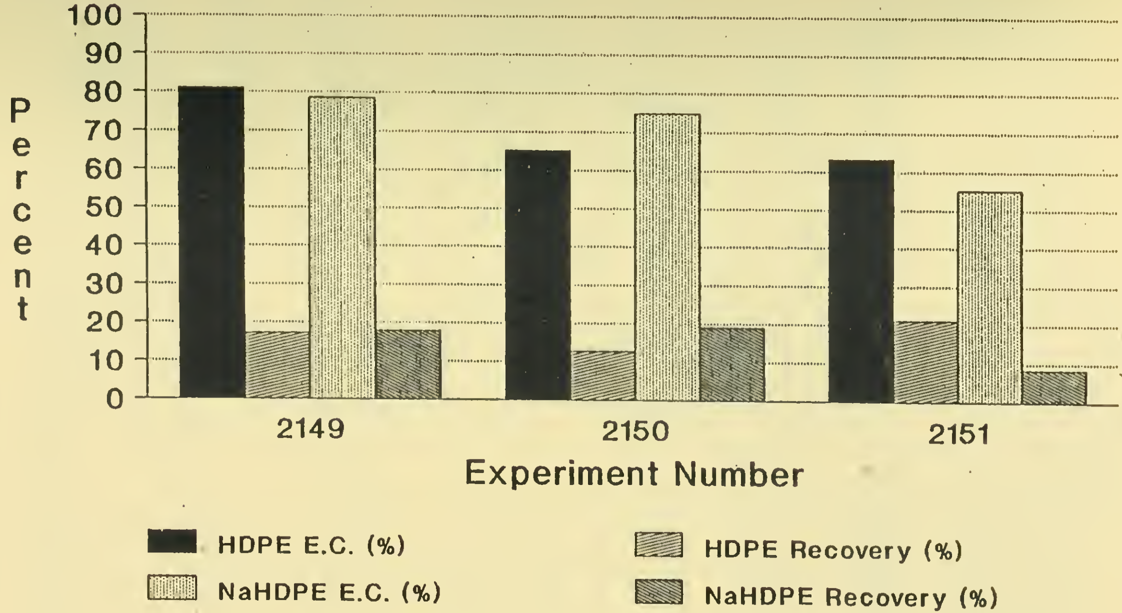

PP/PS Separation
Various Initial Compositions
Percent
100
90
80
70
60
50
40
30
20
10
0
PP/PS 50/50
PP/PS 5/95
PP/PS 1/99
Initial Composition
PP E.C. (%)
PS E.C. (%)
PP Recovery (%)
PS Recovery (%)

Figure 8



Initial Composition 50/50

Figure 9

CONCLUSIONS

The experimental study carried out in the Applied Electrostatics Research Laboratory of the University of Western Ontario has proven that:

1. Excellent separations in terms of extract contents (purity) and recoveries may be achieved with the following 2 component mixtures.

FEED STREAM	INITIAL COMPOSITION %	EXTRACT CONTENT (OR PURITY) (%)	RECOVERY (%)
PVC PET	50.0 50.0	99.2 99.9	80.3 89.1
PVC PET	1.0 99.0	3.6 100.0	64.0 79.4
HDPE PP	50.0 50.0	99.6 99.7	84.3 89.3
HDPE PP	90.0 10.0	99.9 43.9	84.6 95.0
PP PS	50.0 50.0	94.1 98.8	96.2 91.9
PP PS	5.0 95.0	30.9 99.9	95.0 85.1

2. Certain three component mixtures are separable with extract contents and recoveries as shown in the table below.

FEED STREAM	INITIAL COMPOSITION %	EXTRACT CONTENT (OR PURITY) (%)	RECOVERY (%)
HDPE PP PS	42.5 42.5 15.0	92.0 96.1 99.6	72.2 90.7 73.8

NOTE: The above separation results were based on post-industrial waste except for the PET/PVC separation (1%/99%) which involved post-consumer waste.

ACKNOWLEDGEMENTS

I. The research team wished to acknowledge with gratitude the financial support from the Ministry of the Environment, Waste Management Branch to carry out this project and the excellent cooperation received from MOE Scientific Liaison Officer (Mrs. Irene Pater.)

II. The technical advice and material support received from EPIC (Environment and Plastics Institute of Canada) an in particular from Dr. Fred Edgecombe who was part of the executive team of the project.

Dr. Edgcombe's contribution has been a key factor in the success of this project.

Availability of New Technology.

The technology developed during the course of this study is available for licensing. Interested parties can contact one of the following for more information:

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Waste Management Branch
2 St. Clair Ave West, 14th Flr.
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Executive Director
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Professor Ion Inculet
Director, Applied Electrostatics Research Centre
The University of Western Ontario
London, Ontario
N6A 5B9

APPENDIX A

Tables with Results

APPENDIX

Test Number	R.H. (%)	Temp (°C)	Plastic	Initial Comp (%)	E.C. (%)	Recovery (%)
2051	47.6	28.4	PVC (-)* PET (+)	50.0 50.0	97.9 97.9	73.5 74.0
2052	34.3	27.8	PVC (-) PET (+)	50.0 50.0	94.9 99.3	75.6 76.6
2053	34.3	27.8	PVC (-) PET (+)	50.0 50.0	99.1 99.3	74.3 89.7
2054	43.7	27.8	PVC (-) PET (+)	50.0 50.0	99.2 99.9	80.3 89.1
2055	40.5	28.2	PVC (-) PET (+)	50.0 50.0	99.6 99.2	79.4 85.6
2056	40.9	28.4	PVC (-) PET (+)	50.0 50.0	98.6 99.1	86.0 83.4
2057	28.0	26.4	HDPE (-) PP (+)	50.0 50.0	65.2 47.8	6.7 8.2
2059	33.6	24.6	HDPE (-) PP (+)	50.0 50.0	93.8 44.8	29.3 7.3
2061	34.3	23.3	HDPE (-) PP (+)	50.0 50.0	98.9 81.0	61.7 28.4
2063	33.4	25.4	HDPE (-) PP (+)	50.0 50.0	97.0 80.9	45.1 24.1
2065	34.4	24.8	HDPE (-) PP (+)	50.0 50.0	95.8 61.0	42.1 14.4
2084	43.8	25.0	HDPE (-) PP (+)	50.0 50.0	99.9 99.7	90.6 92.6
2085	43.8	25.0	HDPE (-) PP (+)	50.0 50.0	99.8 99.7	85.2 93.1
2086	41.5	23.4	HDPE (-) PP (+)	50.0 50.0	99.6 99.7	84.3 89.3
2087	41.4	23.7	HDPE (-) PP (+)	50.0 50.0	99.9 99.4	83.5 89.9
2088	40.5	23.9	HDPE (-) PP (+)	50.0 50.0	99.3 99.5	87.5 91.7

* - Sign indicates charge acquired
(-) Negative; (+) Positive; or None (N)

Test Number	R.H. (%)	Temp (°C)	Plastic	Initial Comp (%)	E.C. (%)	Recovery (%)
2133	47.9	22.7	HDPE (-) PP (+)*	75.0 25.0	99.1 94.2	91.4 96.7
2134	51.1	23.6	HDPE (-) PP (+)	80.0 20.0	99.3 83.2	91.5 95.4
2135	49.2	23.3	HDPE (-) PP (+)	90.0 10.0	99.9 43.9	84.6 95.0
2138	49.2	22.1	HDPE (-) PP (+)	10.0 90.0	83.5 99.3	92.5 96.8
2139	51.3	22.2	HDPE (-) PP (+)	20.0 80.0	94.2 99.0	95.6 97.3
2140	48.3	21.8	HDPE (-) PP (+)	25.0 75.0	97.9 99.2	90.2 98.0
2149	49.1	23.4	NaHDPE(-) HDPE (+)	50.0 50.0	78.5 81.0	17.9 17.1
2150	50.6	24.4	NaHDPE(-) HDPE (+)	50.0 50.0	74.8 65.3	19.0 12.7
2151	51.0	25.5	NaHDPE(-) HDPE (+)	50.0 50.0	55.2 63.4	8.5 21.1
2160	45.9	20.3	PP (-) PS (+)	50.0 50.0	94.1 98.8	96.2 91.9
2161	45.9	20.3	PP (-) PS (+)	5.0 95.0	30.9 99.91	95.0 85.1
2162	41.6	21.5	PP (-) PS (+)	1.0 99.0	7.4 99.97	83.0 86.6
2175 2176	30.0	19.3	HDPE (-) PP (N) PS (+)	42.5 42.5 15.0	92.0 96.1 99.6	72.2 90.7 73.8
2177 2178	31.5	20.0	HDPE (-) PP (N) PS (+)	42.5 42.5 15.0	95.2 97.9 99.6	66.9 92.2 73.8
2179 2180	31.6	18.5	HDPE (-) PP (N) PS (+)	42.5 42.5 15.0	94.0 96.9 98.8	64.7 92.7 67.8

* - Sign indicates charge acquired
(-) Negative; (+) Positive; or None (N)
HDPE/PP/PS mixtures involved two stage processing

Notes: R.H. - Relative Humidity of Air
Temp - Air Temperature
Initial Comp - Weight Percent in Feed Stream
E.C. - Extract Content
PET - Polyethyleneterephthalate
PVC - Polyvinylchloride
HDPE - High Density Polyethylene (Coloured)
NaHDPE - High Density Polyethylene (Natural)
PP - Polypropylene
PS - Polystyrene

APPENDIX B

Executive Summary

Final Report on the Phase 1 of the Project:

Separation of Mixed Plastic Waste Using Electrostatics Phase I

Supported by MOE-WASTE Management
(File No. WP/EG, 8098AG INR 04 215)
& EPIC

Attention:
Mrs. Irene Pater, Ministry of the Environment
and
Dr. Fred Edgecombe, Environment and Plastics Institute of Canada

Research Assistants
Quig Wen
Ting C. Yu

Investigators
I.I. Inculet
G.S.P. Castle
J.D. Brown

27 August 1991

Executive Summary

The Phase I of the project focused on determining the feasibility of using several existing electrostatic separation systems previously developed at the Applied Electrostatics Research Centre (AERC) of the University of Western Ontario for beneficiation of mineral ores. The research team carried out plastics separation experiments with: a. The Tower, b. the Conveyor with Troughs, c. the Dilute Phase Loop, and d. the Vibrated Fluidized Bed.

After a considerable number of experiments with the four systems it was concluded that the tower was the most promising, readily available system. The other three would require some major modifications to make them suitable for the separation of plastics in lieu of mineral ores.

The following mixtures of plastics where investigated:

I PVC (flakes) and PET (flakes)

II HDPE (Brown, granular) and (Natural HDPE (White, flakes) designated in the report as "PE")

III PP (flakes) and HPDE (granular)

This final report on the phase I, presents the results of (82) experiments carried out in the electrostatic tower using two different feeding systems:

a) A fluidized bed - [known technology]

b) A Syntron Vibrator combined with a rotating tube [novel system, very likely suitable for patent protection].

In the first set of experiments, the plastics came from manufacturing rejects. Subsequent test were carried out with washed materials.

The results to date have been most encouraging and they are presented in this report in terms of:

I. % Extract Content = Ratio of:

$$\frac{\text{mass of sought component in the extracted fraction in a bin}}{\text{mass of the extracted fraction in the same bin}}$$

II. % Recovery = Ratio of:

$$\frac{\text{Cumulative mass of sought component in the extracted fractions from several bins.}}{\text{Total mass of the sought component in the processed batch}}$$

Some typical results from single stage separation:

A. With the fluidized bed feeding system using rejected materials:

- From a mixture of 50/50 PET flakes and PVC flakes, it has been possible to recover 92.37% of the PET material with an extract content of 100%. (Experiment No. 1.)

  In the same experiment, the recovery of the PVC was 86.53% with an extract content of 99.71%.

- From a mixture of 50/50 HDPE granular and PE flakes, it has been possible to recover 22.42% of the HDPE material with an extract content of 89.18%. At the same time the recovery of the PE was 47.14% with an extract content of 70.47. (Experiment 31.)

- From a 50/50 mixture of HDPE granular and PP flakes, it was possible to separate a PP fraction with an extract content of 99.45%. However, the PP recovery was only 15.69%. At the same time the HDPE recovery was 83.08% with an extract content of 61.91% (experiment No.29).

B. With the fluidized bed feeding system using washed PET material there were similar, very encouraging results obtained as shown in table I.

Table I **Summary of a few Promising Experiments with washed PET**

Exp. No.	Materials	H.V. (KV)	R.H.% Room/C.AIR	Temp.(^0C) Room/C.Air	P.C. FEED TIME(MIN)		Bin No	E.C.%	Recovery
57	PET*-PVC	100	55.5/12.6	25.1/25.0	5.00/10	PET*	7-9	99.82	83.47
						PVC	1-3	96.07	84.07
58	PET*-HDPE	100	45.5/12.1	26.8/27.6	5.00/10	PET*	7-9	99.88	40.54
						PDPE	1	85.35	85.35
59	PET*-PP	100	64.2/12.3	26.4/26.2	5.00/16	PET*	7-9	99.58	71.00
						PP	1-2	97.18	93.29

C. With the Rotating Tube and the Sytron Vibrator Feeding System

This series of experiments was carried out with rejected materials only.

With the rotating tubes, the tube materials contribute significantly to the final charge on the plastic particles. Experiments were carried out with four tube materials: copper, aluminum, PVC, and ABS. Some of the results for these very preliminary experiments, have been very encouraging:

- An experiment with a 50/50 mixture of PET and PVC fed in the electrostatic tower with a PVC tube, demonstrated the feasibility of recovering 79.2% of the PET with an extract content of 100% (perfectly pure PET).

  In the same process, the PVC recovery with an extract content of 95.04% was only 70.53%. [Experiment #73]

  Using an ABS tube, the PET extract content was 99.73% at a recovery or 74.77% whereas the PVC recovery was substantially increased to 95.34% with an extract content of 98.21%. [Experiment #74]

  The final report contains complete details of the experiments.

D. Preliminary Experiment for separation of 3 component mixtures using the rotating tube and Syntron Vibrator feeding system into the Electrostatic Tower.

The experiment involved 2 stage separation of a mixture of 20 gram PET plus 20 gram PVC plus 20 gram HDPE.

In this very preliminary trial it was possible to extract a PVC fraction with a 98.16% extract content at a recovery of 69.16%. The PET and HDPE fractions will require additional separation stages in order to achieve extract contents higher than 99%. [Experiment #75]

Notes:

- The extract contents and recovery figures quoted in this Executive Summary represent collections of 2 or 3 bins only out of the array of 9 bins at the bottom of the Electrostatic Tower. The graphs of recovery and extract content for each experiment which are given in the report allow one to estimate the extract contents for various sought recoveries.

- Out of the 82 experiments, only one experiment (experiment 75 a,b,c,d, & e involved a 2 stage electrostatic separation.)

Conclusions

I **This preliminary phase of the project has given most encouraging results with only one separation stage.**

II **The outstanding results achieved in the separation of PET and PVC which showed the possibilities for achieving 100% extract content for the PET are of considerable interest to the industry.**

III **The research team of the Applied Electrostatics Research Centre feels confident that the proposed phase II of the project will provide powerful technology to the industry for recycling plastics.**